1976

Financial analysis of alternative ponderosa pine tree breeding programs

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A FINANCIAL ANALYSIS OF ALTERNATIVE

PONDEROSA PINE TREE BREEDING PROGRAMS

by

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B.S.B.A., Georgetown University, 1970

Presented in partial fulfillment of the
requirements for the degree of

Master of Science in Forestry

UNIVERSITY OF MONTANA

1976

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March 30, 1976
Date

1-1-76

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ABSTRACT

Keegan, Charles E. III, M.S., 1976 Forestry

A Financial Analysis of Alternative Ponderosa Pine Tree Breeding Programs

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Two ponderosa pine (Pinus ponderosa, Laws.) tree breeding systems were evaluated in a series of analyses as an alternative to the use of nursery run stock in reforestation programs.

Internal rate of return and net present worth at a 3% and a 10% discount rate were used to rank the programs in the analyses.

The use of genetically improved stock for reforestation yielded internal rates of return ranging from 4.5% to 7.25%. The internal rates of return for the user of nursery-run stock ranged from 4.5% to 7.1%. In all but one analysis, the rate of return from the tree breeding programs ranked above the rate of return for nursery stock. The largest difference, however, was only .15%.

When evaluated by net present worth at a 3% discount rate, the rankings of the programs coincided with the internal rates of return. The relative differences in the net present worth of the alternative programs were much larger than the relative differences in internal rates of return.

When a 10% discount rate was used, all of the proposed programs yielded a negative net present worth. The tree breeding programs ranked below the use of nursery run stock in each analysis.

Although the results of the analyses may cast some doubts on the financial advisability of ponderosa pine tree improvement programs, a definite determination could not be made because the revenue factors considered in the analyses are believed to be conservative. The only benefit attributed to the breeding programs was a genetic gain in volume based on variation in height growth among two-year-old seedlings. The tree breeding programs offer a multitude of additional benefits which could not be quantified in the analyses. These benefits include increased diameter growth, improved tree crop security, more uniform stands of trees, heterotic gains, and many additional non-market values. The desirability of the tree breeding programs, relative to the use of nursery run stock, is increased by each of these additional benefits. A forest investor should consider this when evaluating tree improvement programs.

ACKNOWLEDGMENTS

I express my sincere appreciation to my major advisor, Dr. George M. Blake, who provided guidance and direction for this thesis.

Special thanks are extended to Dr. George E. Howe, Dr. Howard E. Reinhardt, and Dr. Richard E. Shannon, who, as members of my graduate committee, offered their advice and beneficial criticism.

In addition, I would like to thank Dr. Rudy Gideon, Dr. Donald Loftsgaarden, and Dr. Hans Zuring for their help in the design of the statistical analyses used in the thesis.

Appreciation is also given to Mr. Jeffrey Madsen, Mr. Mel Morton, Dr. Ervin Schuster, and Ms. Lydia Undem and to the cooperators of the Inland Empire Tree Improvement Committee for assistance in developing this study.

Financial assistance for this study was provided by the McIntire-Stennis Fund.

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CHAPTER I

INTRODUCTION

The Forest Service predicts both a decline in forest land available for timber production and an increase in demand for forest products well into the 21st century (Anon, 1972). To meet this timber supply problem in Region I, selective breeding programs have been proposed for all of the important commercial timber species. A selective breeding program includes the selection of trees to serve as initial seed sources and the identification and subsequent mating of genetically superior progeny. Similarly, gains may accrue to a program from both phenotypic selection in the wild and from mating selected progeny.

Genetic variation is the ultimate source of gains from all selective breeding programs in forest trees and no gains are possible if sufficient genetic variation does not exist within the forest tree species. In general, the source of greatest genetic variation within a species is ecotypic in nature. Ecotypic variation is then generally followed in descending order of magnitude by genetic variation between populations, stands of trees, and then between individuals within populations.

Ecotypic variation derives from the adaptation of the species to regional environmental factors such as climate (Stern and Roche, 1972). Regional environmental differences contributing to the formation of ecotypes within a species are generally quite large and individuals are often unfit when moved to the range of another ecotype. Most tree breeding programs, therefore, utilize stand-to-stand and tree-to-tree variation within the geographic area of the ecotype as the basis for a tree breeding program.

The maximum genetic gain available to a program is fixed by the usable genetic variation in the population. The geneticist's ability to utilize genetic variation is dependent upon the selection intensity employed and the sophistication of the genetic evaluation test and subsequent mating design. A breeding system based on stand-to-stand variation utilizes a less sophisticated genetic evaluation design than does a program based on the selection of individual trees. A program based on stand selection should, in general, result in a lower genetic gain than one based on individual tree selection.

The tree breeding program yielding the largest genetic gain is not necessarily the most desirable. Genetic gain is only meaningful when it is related to the cost of the program used to secure that gain. Nearly every organization practicing intensive forestry on a large scale is faced with a shortage of funds, and a financial analysis should be used to choose between alternative improvement programs. Furthermore, tree breeding is not the only avenue available to secure gains from forest lands. An organization must be able to direct its resources into the economically most advantageous practices. If tree breeding programs do not provide satisfactory returns, they may be abandoned in favor of other silvicultural practices.

Financially, ponderosa pine (Pinus ponderosa, Laws.) appears to be a prime candidate for a tree improvement program. It is the most important species of pine in the western United States. Normally in the Inland Empire[1], its stumpage value is exceeded only by western white pine (Pinus monticola, Dougl.) and western red cedar (Thuja plicata, Donn.) (Swift, 1976). In spite of these facts, little is known about the potential of ponderosa pine to respond to genetic selection for growth traits. Previous studies have demonstrated that genetic variation in relation to growth characteristics does exist in ponderosa pine (Callaham and Liddicoet, 1961; Wells, 1964; Squillace and Silen, 1962; Weidman, 1939).

These studies have either been studies of broad geographic variation (Wells, 1964; Weidman, 1939) or they have been very narrow in scope (Callaham and Liddicoet, 1961; Wang, 1974). In addition, very little of this work has been directly involved with the production of genetically improved stock to be used in reforestation programs, and as of 1970, only 20 acres of ponderosa pine seed orchards existed in the United States (Anon, 1974). Squillace and Silen (1962) have shown, however, that seed sources from other geographic areas do not perform well in the Inland Empire. Ponderosa pine tree improvement work in the Inland Empire should, therefore, utilize genetic variation between stands and between trees within stands. The objectives of this study were:

1/ The Inland Empire is the region of the northwestern United States between the Rocky Mountains and the Cascade Mountains, embracing portions of eastern Washington, northeastern Oregon, northern Idaho, and western Montana.

1) To evaluate the effectiveness of the selection, based on wild performance, of individual superior trees from within selected stands as a seed source in a ponderosa pine breeding program in the Inland Empire.
2) To evaluate, through a financial analysis, a ponderosa pine tree improvement program utilizing a breeding system based on individual tree selection versus one utilizing stand selection.
3) To evaluate the above listed programs by means of a financial analysis as an alternative to the use of nursery run stock for reforestation purposes.

CHAPTER II

SCOPE

An individual tree breeding program is based on the selection, in the wild, of phenotypically superior individual trees selected from phenotypically superior stands. Seed from these trees is grown as open-pollinated families in genetic evaluation plantations. The plantations are converted to seed orchards at some future date by the elimination of inferior families and inferior trees within families.

A stand selection breeding program is based on the collection of seed from phenotypically superior wild stands. Seed from these stands is bulked by stand and grown as group lots in genetic evaluation plantations. These plantations are converted to seed orchards by the elimination of inferior group lots and inferior trees within group lots.

The establishment of separate genetic evaluation plantations and seedling seed orchards allows only for selection based on family or group lot mean performance. In both of the above cases, it was assumed that plantation material would be used as seed producers. This was done to permit within stand and within family selection based on individual tree performance.

Gains from Tree Breeding Programs

As stated above, genetic gains may be achieved by phenotypic selection from natural stands and from mating selected individuals on the basis of genetic evaluation tests. Gains from selection in the wild are dependent not only on the amount of genetic variation and on the selection intensity applied, but also on the difficulty of identifying superior genotypes under wild conditions. A great deal of controversy exists as to the benefit of expenditures to secure gains in growth traits from selection based on wild performance. Growth characteristics in trees are traits of low heritability and weak genetic control (Rohmeder, 1961). Heritability represents "the proportion of observed variability which is due to heredity, the remainder being due to environmental causes" (Allard, 1960). Under conditions of low heritability, therefore, environmental factors can have a large effect on the phenotypic variation of growth characteristics in trees. This makes the selection of superior genotypes based on individual phenotypes a difficult proposition.

The silvical characteristics of ponderosa pine suggest that successful phenotypic selection may be possible both between stands and between individual trees within stands. Ponderosa pine is a pioneer species on most of the sites on which it is found in the Inland Empire and it often occurs in even-aged stands. "An even-aged fully stocked, naturally regenerated stand is generally a better and more reliable indicator of the genetic constitution of the subpopulation than an isolated individual tree is of its own genetic character" (Anon, 1972).

If significant genetic variation exists between individuals within stands, then additional gains are possible if superior individual genotypes can be identified. An even-aged stand with a relatively homogenous environment could possibly serve as an unreplicated genetic evaluation test of the individuals within those stands. As previously stated, heritability for growth traits is low, especially in wild stands. This means that much of the phenotypic variation is caused by environmental influences. However, under even-aged conditions on relatively homogeneous sites, environmental variation will have a reduced effect on the observed variation in growth rate between individuals on that site. In this case, heritability may be high enough to make the phenotypic selection of individual trees successful.

Gains from the subsequent mating of genetically evaluated progeny are dependent on the genetic variability of the test population and on the precision of the estimates of variation and heritability allowed by the test design and by the mating scheme. If significant variation does not exist within stands, then a less expensive evaluation design in which selection is first made between group lots can be as effective as a design in which selection is made between open pollinated families. If significant variation does exist within stands, a breeding program based on stand selection will lower the gains available to that program.

CHAPTER III

METHODS AND MATERIALS

In 1968 a cooperative tree improvement program in ponderosa pine was initiated by the Inland Empire Tree Improvement Committee. Prior to 1972 the cooperators selected as seed sources 434 individual trees from throughout the Inland Empire (Figure 1). The stands and trees were selected on the basis of growth rate, crown form, bole form and freedom from insect and disease attack.

The cooperators were instructed to collect seed from the individual selected trees and also to collect a random sample of seed, referred to as group lots, from throughout each stand. The seed was sown at the Coeur d'Alene National Forest Nursery in May of 1972 in a randomized complete block design with three blocks of both the open-pollinated families and grouped stand seedlots. The seedlings from these seedlots have since been outplanted to eight progeny test sites and two seed orchards.

The progeny from the 93 stands were grown in the Coeur d'Alene Nursery for two years. In October of 1973, height measurements were taken in the nursery. Five seedlings were measured within each family for each block and ten seedlings were measured for each group lot in each block. Only the average heights for each family and group lot for each block were recorded. Within family measurements were recorded from sixty families chosen at random from the three blocks to estimate within family variance. Since both progeny from individual

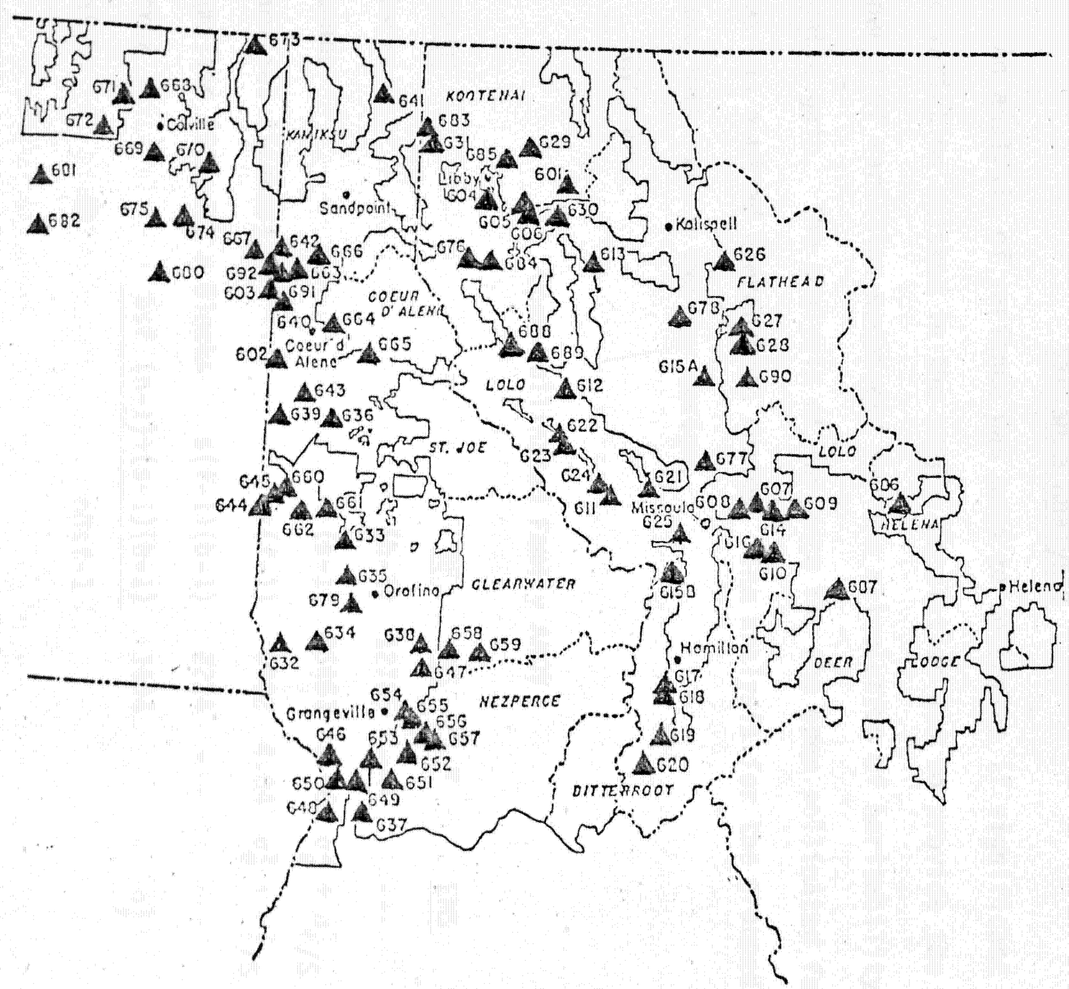

Figure 1. Location and Designation of Stands in the Inland Empire Tree Improvement Committee's Ponderosa Pine Project

selected trees within stands and progeny representing random seed samples from that stand were grown together, a comparison of the heights of the two by a paired sign test was proposed to evaluate the effectiveness of the individual tree selection process.

Variance Analysis

An analysis of variance was used to determine if significant genetic variation existed in the sample population and to provide the components of variation necessary for the calculation of heritability and genetic gain. The analysis of variance for the open pollinated families was a mixed hierarchial design. The analysis for the grouped stand lots was a two-way design.

They are:

Open-Pollinated Family ANOV

Source	DF	MS	F	EMS
Blocks	(b-1)	12785	---	---
Stands	(s-1)	25461	3.66	$\sigma^2_e + \sigma^2_{F/S} + \sigma^2_S$
Families (Stands)	s(f-1)	6952	4.04	$\sigma^2_e + \sigma^2_{F/S}$
Families (Stands) x Blocks	s(f-1)(b-1)	2224	---	---
Error	bsf (n-1)+(s-1)(b-1)	1404		σ^2_e
Total	nbsf-1			

Grouped Stand Lot

Source	DF	MS	F	EMS
Blocks	(b-1)	2121	---	---
Stands	(s-1)	1096	3.70	$\sigma^2_E + \sigma^2_S$
Error	(b-1)(s-1)	296		σ^2_E
Total	bs-1			

In the case of the open-pollinated families, twenty-one of the stands were represented by an inadequate number of families (less than five) and could not be included in the analysis of variance. In addition, 48 of the group lots were not true random collections of seed from within the stands and were not included in the two-way analysis of variance used in the stand lot analysis.

Heritability and Genetic Gain

An estimate of heritability and genetic gain was calculated for the individual tree breeding scheme based on a formula developed by Namksoong et al. (1966) for estimating genetic gain from an open-pollinated seedling seed orchard composed of half-sib families. Heritability for the open-pollinated families was calculated as follows:

Heritability = b = K $\frac{\sigma^2_{A'}}{\sigma^2_2}$ where K = the fraction of the total additive genetic variance in the covariance of the additive values in this case k = ¼ for half sibs. The open-pollinated families were assumed to be half sibs, however; members of the same open-pollinated families may bear other familial relationships.

Genetic gain is calculated as follows:

$$\Delta G = (i_1 \frac{\frac{1}{2}\sigma^2_A}{\sigma_1{}^2} \sigma_1 + i_2 \frac{\frac{1}{4}\sigma^2_{A'}}{\sigma^2_2} \sigma_2 + i_3\ 3/4 \frac{\sigma^2_{A''}}{\sigma_3} \sigma^2_3)$$

where:

ΔG = genetic gain

σ^2_1 = phenotypic variance in the population

σ^2_2 = phenotypic variance of the half-sib family means

$\sigma^2{}_3$ = within half-sib family phenotypic variance

σ^2_A = additive genetic variance in the original population

$\sigma^2_{A'}$ = additive genetic variance in the selected population

$\sigma^2_{A''}$ = additive genetic variance after selection mating and genetic recombination. It can be assumed that $\sigma^2_A = \sigma^2_{A''}$ (Shelbourne, 1972).

(i_1, i_2, i_3) = the mean value for the trait in the original population and the mean value in the select population expressed in units of standard deviation (Falconer, 1960).

It was not possible to calculate a meaningful figure for heritability from the group lot data because no within stand measurements were recorded when the height data was taken. Since heritability is a "character" of the population itself (Wright, 1969) and since the stand lots and half-sib families are to some degree equivalent populations, the open-pollinated family data was used in the calculation of heritability for the stand lots. It was calculated as follows:

$$b = \frac{3/4\sigma_{A''}^2 + 1/4\sigma_{A1}^2}{\sigma_4^2}$$

$$\sigma_4^2 \approx \sigma_3^2$$

Total phenotypic variance was calculated for the group lots from the analysis of variance. The above heritability estimate was applied to this total phenotypic variance to determine genetic gain for the stand breeding system, where

$$\Delta G = i_1 \frac{\frac{1}{2}\sigma_A^2}{\sigma_1} \sigma_5^2 + \frac{i_4 \sigma_{A'''}^2}{\sigma_4{}^2} \sigma_5{}^2 \quad \text{(Shelbourne, 1972)}$$

and σ_5^2 = total phenotypic variance for the group stand lots.

For the sake of comparison in determining genetic gain, selection intensity was assumed to be the same for both systems. The selection intensities used in the calculation of genetic gain were for the upper one percent of the wild population in both breeding systems. Selection in the genetic evaluation plantations was for the upper 25 percent of the open pollinated families or group lots and for the upper 25 percent of the individuals within families or groups.

The Economic Analysis

An economic analysis requires the translation of genetic gains into dollar revenues and the evaluation of the revenues in terms of the cost incurred to secure them. Revenues from a tree improvement program are dependent on three major factors, the genetic gain for the trait or traits involved, the economic value of that trait, and the amount of genetically improved seed produced by the program.

All of the above listed factors which enter into the determination of revenues for a tree improvement program are subject to a great deal of variation because of the uncertainty of predictions made twenty to two-hundred years into the future. For this reason, a base analysis was proposed and evaluated on certain assumptions made concerning the amount of genetic gains from the program, the economic value of the product, stumpage price, and the amount of genetically improved seed produced by the program. Additional analyses in which one or more of the above-mentioned factors were varied were then proposed and evaluated. This was done to demonstrate the sensitivity of the cost analysis to different levels of the revenue factors.

Total revenue for the alternative programs was calculated as the product of stumpage price, volume production per acre from Meyer's Normal Yield Tables (Meyer, 1938), genetic gain, and the total number of acres planted. Revenue per year for the tree improvement programs was calculated as follows:

Total Revenue/Year = (1 + genetic gain) (Stumpage Price) (Volume/Acre) (Acreage Planted/Year).

Total costs to date were determined from the records of the tree improvement committee. Estimates on future costs were made by the cooperators. These costs were then allocated to the breeding systems based on questionnaires filled out by the cooperators and cost data supplied by the Coeur d'Alene Nursery (Appendix I).

Analysis I: The Base Analysis

This analysis and all subsequent analyses consisted of three basic alternatives. The alternatives were reforestation programs using genetically improved stock from the individual tree breeding system, the stand breeding system and reforestation with genetically unimproved stock. In all cases, net present worth and internal rate of return was used to evaluate the alternatives. Net present worth is the value today of present and future gains minus future costs discounted at some desired discount rate (Dyrland, 1970). Internal rate of return is that discount rate which exactly equates the present worth of present and future returns with the present worth of present and future costs (Dyrland, 1970). The calculations were done by the Invest III Forest Service Program for the economic analyses of resource management alternatives.

The input factors for the revenue equation were determined as follows:

Gain in Volume for Genetically Improved Stock. The genetic gains were calculated based on the height of two-year-old seedlings in the nursery. Gains in height growth mean at least proportional gains in volume growth. The assumption was made here that these percent gains in volume growth would be available at rotation age.

Current plans call for the use of genetically improved stock only on productivity classes 1 and 2 in Region 1 (Howe, 1973). Since the need for ponderosa pine seed on class 1 lands is very small in comparison with the need on class 2 lands, it was assumed here and in all subsequent analyses that all of the stock would be planted on class 2 lands. Meyer's site index 110 is equivalent to medium site class 2 lands. Gains in volume yield were calculated by applying the percent genetic gain to the volume given in Meyer's yield tables for the projected rotation age. In the case of unimproved stock, Meyer's volume yield values were used.

Rotation Length. For site index 110 from Meyer's yield table for even-aged ponderosa pine, the point of maximum volume productivity over repeated rotations was determined from the intersection of the periodic annual increment and mean annual increment curves to be eighty years. When costs are incurred in establishing a stand of timber, financial factors can become important in determining the rotation length. Compound interest rates applied to the establishment costs generally make shorter rotation lengths more desirable from a financial standpoint. To demonstrate the effect of interest on a financial analysis of the three programs, the base analysis was run at an eighty-year and a sixty-year rotation length.

Stumpage Price. Current projections call for an increase in stumpage prices in real dollars at the rate of 1.5% per year into the Twenty-First Century (Anon, 1972). Base stumpage prices for the harvest cuts were computed by averaging the stumpage prices for the years 1968 through 1972. This average base stumpage price was adjusted upwards at the rate of 1.5 percent per year to the year of initial harvest. This stumpage value was used in the calculation of all revenues for the analyses.

Seed Production in the Orchards. Seed production in this base analysis was estimated from the seed production of wild trees (Schmidt and Shearer, 1970). The open pollinated family plantations given wild tree conditions would be capable of producing enough seed to plant on the average 4500 acres per year. The stand breeding program was somewhat smaller than the open-pollinated family program. The costs of the stand breeding program were therefore adjusted upwards to the level of expenditures needed to establish a program capable of producing enough seed to plant 4500 acres per year. The use of unimproved stock was evaluated based on the planting of 4500 acres per year.

Revenue from Intermediate Cuttings. If the material removed in intermediate cuttings is merchantable, then the revenue generated can have a significant effect on the profitability of the tree breeding program. In the Inland Empire, however, thinnings to remove merchantable size material in ponderosa pine are generally a break-even proposition at best (Host, 1976). Therefore, revenues from intermediate cuttings were not included in these analyses.

Analysis II: An Increase in Seed Production in the Seed Orchard

Seed production is a critical factor in the determination of the financial feasibility of a tree improvement program. The higher the seed production per tree in the orchard, the lower the genetic gain needed to justify the program. No reliable estimates of seed production from orchards could be obtained, but predictions indicate that under orchard conditions, seed production should be at least three times as high as under wild conditions (Shearer, 1975). A second level of seed production at triple the wild tree estimate was used to calculate revenues for both the 60-year rotation and the 80-year rotation proposed above.

Analysis III: The Programs at Today's Stumpage Prices

Stumpage price is the most uncertain of all the factors affecting the revenue derived from the various alternatives. In the last five years, the average stumpage price for ponderosa pine in Region One has varied from a low of under \$20 per thousand board feet to a high of over \$200 per thousand, and as a result, it becomes difficult to determine a current stumpage price to be used in an analysis. Because of this, I have chosen a figure of \$75 per thousand board measured used in a previous cost analysis of this ponderosa pine project (Howe, 1974). It represents the average value of timber in May of 1973. A cost analysis of the three alternative programs was run for 60- and 80-year rotations at both seed production levels using this stumpage value.

CHAPTER IV

RESULTS

Individual Tree Selection

In nearly every case, the average height of the stand lots was higher than those of the individual selected tree lots. Spacing appears to be responsible for the increased growth of the grouped stand seedling since individual tree selection should not have a negative impact on the relative height growth of the progeny. The grouped stand seed was sown in lots that were approximately 2' by 2' and the open-pollinated family seed was sown in lots that were approximately 6" by 2'. Because of the difference in the spacing, the effectiveness of individual tree selection could not be tested with the nursery data. In agricultural plants, variance was generally less affected by changes in spacing than were genotypic rank relationships (Evans et al., 1966). The assumption was made that the variance of the grouped lots was not significantly affected by a different spacing design. A comparison of genetic gain based on the variance of each breeding subpopulation was then used to assess the two breeding systems.

Variance Analysis: Heritability and Genetic Gain

The analyses of variance showed significant variation (at the 1% level) between group lots in both cases and between families in the open-pollinated family design (Table 2).

Estimated heritability was 38% for the open-pollinated families and

25% for the stand lots. The estimate for the stand lots was lower because it represents heritability calculated on the basis of individual tree performance (Wright, 1963). These heritability estimates are meaningful only in terms of the breeding system for which they were calculated (Shelbourne, 1972).

Estimated genetic gain in height growth and therefore volume production was 13.2% for the open-pollinated family system and 6% for the stand breeding system.

The Cost of the Programs

For purposes of my analysis, I divided the programs into five phases, the progeny selection phase, the seed source selection phase, the nursery phase, the seed orchard and test area establishment phase, and the planting and harvesting phase.[1/]

Costs of the progeny selection phase which include all the costs involved in converting the test areas to seed orchards were deemed to be so insignificant in terms of the total costs of the programs as to have no effect on the comparison and, therefore, estimates of these costs were not included in the analyses. This decision was arrived at on the supposition that the value of the material to be rogued - 23-year-old ponderosa pine trees - would be at least equal to the cost of the selection and removal of the inferior performers.

The seed source selection phase included all the work necessary to

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[1/] The cost of the first four above listed phases will be referred to as initiation costs.

select the stands and individual trees, and to collect the cones. This phase represented 17% of the total initiation cost of the program, and it was here that the greatest differential occurred between the two breeding systems. The individual tree program in this phase was $15,250 more expensive than the stand approach.

The nursery phase which included the cost of seed extraction, nursery bed preparation, sowing, maintenance, and finally lifting and sorting, was relatively inexpensive. This phase accounted for only 7% of the total initiation costs. The difference between the two schemes here was less pronounced. The stand approach did, however, result in a savings of $3,150.

The seed orchard and test area establishment phase included the costs of site preparation, planting, mortality replacement, and maintenance costs for the first five years after establishment of the areas. This phase was by far the most expensive. Its cost accounted for 75% of the total initiation costs, and no difference in costs existed between the two programs in this phase.

The total estimated costs are $111,300 for the individual tree program and $92,900 for the stand program. The individual tree program is 20% more expensive to initiate than the stand system (Table 3).

The planting and harvest phase included the cost of growing, shipping and planting the stock to be used in the reforestation programs. Site preparation costs were also included. The figures used represent actual average per acre costs from U.S. Plywood company lands for planting containerized seedlings in western Montana (Hite, 1975).

TABLE 3

Initiation Costs of the Tree Breeding Programs

	Col. (1) Individual Tree Breeding Program	Col. (2) Stand Breeding Program	Col. (1) - Col. (2) Difference
Cost:			
Seed Source Selection Phase	25,450 [1]/	10,200 [1]/	15,250
Nursery Phase	9,550 [2]/	6,400 [2]/	3,150
Progeny test area and seed orchard establishment phase	76,300 [2]/	76,300 [2]/	---
Seed production phase	---	---	---
TOTAL COST	111,300	92,900	18,400

[1]/ Costs were allocated to the two systems based on questionnaires filled out by the cooperators.

[2]/ Detailed Cost Breakdowns were supplied by the Coeur d'Alene Nursery.

The Financial Analyses

Investment decisions can be evaluated only in terms of the goals, objectives and investment opportunities of the organization which is making them. The United States Forest Service, for example, could require a different minimum rate of return on its investments than would a private timber company. If the organization has specified a given rate of return at which alternatives are to be evaluated, then net present worth of the projects at that rate of interest should be used in the evaluation rather than internal rate of return. If on the other hand the organization wishes to choose the given alternative or alternatives yielding the highest rate of return, then internal rate of return can be used. Internal rate of return and net present worth can yield different answers as to the most desirable alternative, depending on the interest rate used in the net present worth calculation. For this reason, I have not attempted to make a recommendation as to what alternative would be the most acceptable or successful in terms of return. I have, however, indicated what alternative is the most desirable if internal rate of return or present net worth at varying interest rates is used to choose a program.

The cooperators in the ponderosa pine tree improvement program may be more interested in the internal rate of return. They have already made the decision to invest in the tree improvement programs and the internal rates of return in the different analyses will provide them with an indicator of the rate of return they can expect to earn on their investment. All of the alternatives in the above listed analyses were ranked by internal rate of return and by net present worth at 2 interest rates - 3% and 10%. The result of these analyses are presented in Appendices 2-4.

Analysis I

Each project alternative with a 60-year rotation ranked above its corresponding project on an 80-year rotation based on internal rate of return and net present worth at both interest rates. If the value of stumpage per thousand board measure is the same for 60- and 80-year-old ponderosa pine, then a 60-year rotation would be the more desirable. This assumption does not hold in today's timber market. Ponderosa pine is currently graded on the stump. Larger and older material is sold at a higher rate than is younger and smaller material. Changes in technology and utilization practices, however, may make stumpage grades unimportant in the future. If this becomes the case, the 60-year rotation is to be favored over the 80-year rotation.

Given a 60-year rotation, the individual tree breeding system showed the highest internal rate of return, 7.11% (Appendix 2). The stand breeding system and the use of unimproved stocks both showed an internal rate of return of 7.10%.[1/]

When net present worth at a 3% interest rate was used to evaluate the alternatives on a 60-year rotation, the individual tree system

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[1/] The author recognizes that these differences are small, the implications of these differences will be discussed further in the conclusion.

ranked first followed by the stand breeding system and then by the use of unimproved stock (Appendix 3).

At 10.0% the effects of a high interest rate on the desirability of the projects becomes apparent. The net present worth of each of the alternatives is negative and their ranking relative to one another is reversed. The use of unimproved stock ranks first on the basis of the smallest negative net present worth and the individual tree system ranks third with the largest negative net present worth. At this higher interest rate, the alternative with the lowest initial cost resulted in the lowest negative net present worth. Conversely, the program with the highest relative cost resulted in the largest negative net present worth (Appendix 4). The predicted gains of the tree improvement programs were not large enough to offset the effects of a 10% interest rate applied to their costs over the time period of the project.

When the alternatives were considered at an 80-year rotation, the individual tree system again yielded the highest internal rate of return, 5.82%. The stand system on an 80-year rotation with an internal rate of return of 5.8% ranked above the use of unimproved stock with an internal rate of return of 5.76% (Appendix 2). The relative rankings of the three alternatives at an 80-year rotation based on net present worth at interest rates of 3% and 10% were the same as those for the 60-year rotation.

Analysis II

Internal rate of return for both tree breeding programs at both rotation lengths increased when seed production in the orchard was tripled. The rate of return of unimproved stock remained unchanged (Appendix 2). All the costs involved in the use of unimproved stock in this analysis were variable and they increased at a rate directly proportional to the increase in acreage planted. The two tree improvement programs on the other hand have considerable fixed costs, and their average total costs per acre planted decreased when seed production in the orchard increased. The two tree breeding programs, therefore, become more desirable relative to the use of unimproved stock as seed production per tree in the orchard increased. The relative rankings of the programs by net present worth at the two interest rates for each rotation was unaffected by an increase in seed production in the orchard (Appendices 3 and 4).

The cooperators currently plan to apply cultural treatments to the seed orchards to stimulate seed production. Clearly these cultural treatments should not be used in the test areas before the selection of seed sources has been made. After these progeny test areas have been converted to seed orchards, however, cultural treatments to increase seed production seem advisable.

Analysis III

When stumpage price is reduced to $75 per thousand and seed production is assumed to be equivalent to wild tree production, only the individual tree selection program ranked above the use of nursery run stock based on internal rate of return and net present worth at a 3% discount rate (Appendices 2 and 3).

The relative rankings of the alternative programs by present net worth at a 10% discount rate at each rotation age were unaffected by the change in stumpage price. At the predicted orchard seed production level the reduction in stumpage did not alter the relative rankings of the project by internal rate of return or by present net worth (Appendices 2, 3 and 4).

CHAPTER V

DISCUSSION AND CONCLUSIONS

The results of this study leave some doubts as to the financial advisability of tree breeding programs. The proposed tree breeding programs yielded higher internal rates of return than the use of nursery run stock in all but one case. The largest difference, however, was only .15%.

The Office of Management and Budget currently expects the U.S. Forest Service to evaluate all of its program alternatives at a discount rate of 10% (Lovegrove, 1976). Clearly none of the programs proposed here under the assumptions given would be acceptable if evaluated on a 10% rate of return.

The gain calculated in the above analyses, however, was calculated based on a gain in height growth alone. Genetic gain may accrue to the program from a number of sources other than height growth. Selection for increased height growth would also, to some extent, be selection for increased diameter growth (Squillace and Roe, 1968). Increased diameter growth would lead to an exponential increase in volume growth.

For example, if a 13.2% increase in height growth yielded a 6.6% increase in diameter growth, then the increase in volume produced at rotation would be approximately 38%. The base analysis yielding a 38% increase in volume on a 60-year rotation would offer an internal rate of return of 9.6% as opposed to the current estimate of 7.1%. This indicates that the cooperators should give careful consideration to the possibility of selecting for increased diameter growth as well as height growth.

Improved tree crop security should result from the selection in the wild of vigorous parent trees demonstrating insect and disease resistance. Furthermore, selection for good crown and bole form should result in a timber crop which can be harvested more efficiently and handled more economically at the mill and "relatively small improvements in the raw materials can have profound effects on mill profits" (Harris, 1969). Organizations which, therefore, operate their own mills can derive benefits from the program which may not be available to the forest land owner. This factor may become more important if mill costs continue to rise at today's rapid rate.

Heterotic gains may occur when crosses are made between trees from separate provenances and gains may accrue to the programs if subsequent selection and breeding stages are added. In addition, increased knowledge of genetic variation patterns in ponderosa pine, improved demarcation of seed transfer zones and many other non-market values may develop from the tree improvement programs.

The intention here is not to imply that if the above gains could be quantified the programs would yield a rate of return of 10% or greater. Initiation costs carried forward to a predicted initial harvest date eighty years in the future at a 10% rate of interest will be increased 2,048 fold in real dollars. "Additional" gains would have to be very large to offset the effect of a 10% interest rate.

A method has been proposed, however, which enables the forest investor in certain situations to shorten the waiting period between the initial costs and the recognition of benefits. If genetically improved stock is planted within areas which have age class distributions and harvest plans in accordance with those proposed for proper application of the allowable cut effect, then "increase in today's allowable cut based on future increase in yields" may be possible (Sweitzer et al., 1972). The use of the allowable cut effect would allow the forestry organization to capture benefits from the use of genetically improved stock at the time of planting rather than at the time of final harvest, thereby reducing considerably the period over which costs with interest must be carried before benefits are derived. The application of the allowable cut effect, when the situation allows it, can result in a substantial rise in the rate of return and may make these tree improvement programs acceptable even if relatively high rates of return are required to justify implementation.

On the other hand, extreme changes, which would negate many of the benefits of a tree improvement program, could take place in the demand for resources from forested lands in the Inland Empire in the next 80 years. These lands even today have many important uses which often are in conflict with the production of timber.

As these uses become more important, land may be shifted from timber production. Obviously if lands planted with genetically improved stock are removed from timber production at some later date, the value of the improvement projects will be reduced. In addition, a change in demand for the different types of wood products or in the technology and cost of production may force the wood products industry out of the Inland Empire in the future. This too would reduce or eliminate any benefits to be derived from the tree improvement program.

Care also must be taken in a tree improvement program to insure that expected genetic gains do not become actual losses. An excessively high selection intensity may result in a reduced gene pool and in a loss of fitness in the reforested population. In addition, if some undesirable characteristic, not expressed or measured in the progeny test, is correlated positively with the selected trait, then gains from the programs may be reduced or eliminated.

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APPENDIX 1

Please fill out one questionnaire for each stand.

Stand number _____

1. Approximate number of man-hours spent in administrative and planning functions for the following years:

   1969 _______
   1970 _______
   1971 _______
   1972 _______
   1973 _______

2. Approximate number of man-hours involved in selecting the stand to be used in the improvement program:

   1969 _______
   1970 _______
   1971 _______
   1972 _______
   1973 _______

3. Approximate number of man-hours involved in selecting the individual plus trees and the alternates to be used in the tree improvement program:

   1969 _______
   1970 _______
   1971 _______
   1972 _______
   1973 _______

4. Approximate number of man-hours spent in scribing, marking, and mapping the plus trees and the alternates:

   1969 _______
   1970 _______
   1971 _______
   1972 _______
   1973 _______

APPENDIX 1 (cont'd)

5. Approximate number of man-hours involved in cone collection from the plus trees:

1969 ________
1970 ________
1971 ________
1972 ________
1973 ________

APPENDIX 1 (cont'd)

Results of the Questionnaire used to Allocate the Seed Source Selection Phase Costs to the Two Breeding Programs Expressed as a Percent of Total Man Hours

	Administration & Planning	Seed Source Selection	Scribing Mapping & Marking	Cone Collection	
Individual Tree Breeding Program	.05	.16	.10	.41	72%
Stand Breeding Program	.04	.06	.02	.16	28%
					100%

APPENDIX 2

Internal Rate of Return

	Analysis I	Analysis II	Analysis III Seed Production Level I	Analysis III Seed Production Level II
Alternative Reforestation Programs				
60-Year Rotation	%	%	%	%
Individual Tree Breeding System	7.11	7.25	6.02	6.11
Stand Breeding System	7.10	7.21	5.42	6.01
Nursery Run Stock	7.10	7.10	5.94	5.94
80-Year Rotation	%	%	%	%
Individual Tree Breeding System	5.82	5.89	4.99	5.03
Stand Breeding System	5.80	5.81	4.50	4.95
Nursery Run Stock	5.76	5.76	4.90	4.90

APPENDIX 3

Rank by Net Present Worth at a 3% Discount Rate

Alternative Reforestation Programs	Analysis I	Analysis II	Analysis III: Seed Production Level I	Analysis III: Seed Production Level II
60-Year Rotation				
Individual Tree Breeding System	1	1	1	1
Stand Breeding System	2	2	5	2
Nursery Run Stock	3	3	2	3
80-Year Rotation				
Individual Tree Breeding System	4	4	3	4
Stand Breeding System	5	5	6	5
Nursery Run Stock	6	6	4	6

APPENDIX 4

Rank by Net Present Worth at a 10% Discount Rate [1]

	Analysis I	Analysis II	Analysis III Seed Production Level I	Analysis III Seed Production Level II
Alternative Reforestation Programs				
60-Year Rotation				
Individual Tree Breeding System	5	3	5	4
Stand Breeding System	3	2	3	3
Nursery Run Stock	1	1	1	1
80-Year Rotation				
Individual Tree Breeding System	6	6	6	6
Stand Breeding System	4	5	4	5
Nursery Run Stock	2	4	2	2

[1] All programs resulted in a negative net present worth when evaluated at a 10% discount rate.